Chemistry Exam
Final Exam
Instructor's Version B

Section I

Time Limit: You have 90 minutes to complete this section.
Scoring: 2 points each; 140 points total; 0.5-point deduction for each incorrect answer.
Resources: You may not use a calculator. You may use the Periodic Table, Equations and Constants sheet, and the Standard Reduction Potentials table.

Answer Sheet

1.	B	15.	D	29.	B	43.	D	57.	E
2.	E	16.	C	30.	B	44.	A	58.	C
3.	B	17.	E	31.	D	45.	C	59.	A
4.	E	18.	C	32.	A	46.	A	60.	B
5.	B	19.	A	33.	E	47.	D	61.	A
6.	A	20.	E	34.	D	48.	B	62.	E
7.	D	21.	D	35.	C	49.	A	63.	C
8.	C	22.	D	36.	C	50.	C	64.	B
9.	C	23.	B	37.	E	51.	B	65.	C
10.	E	24.	C	38.	B	52.	C	66.	E
11.	A	25.	A	39.	E	53.	B	67.	A
12.	B	26.	B	40.	C	54.	C	68.	D
13.	D	27.	D	41.	B	55.	D	69.	B
14.	B	28.	B	42.	B	56.	A	70.	A

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Directions

- Neatly write your responses in the spaces provided. Use a blue or a black pen. Don't write in the margins. Attach additional sheets if needed, and include the submission information on each additional sheet.
- Remember to complete the submission information on every page you turn in.

Section II

Time Limit: You have 40 minutes to complete this section.

Scoring: 64 points total; Question 1 is mandatory and is worth 32 points. Choose EITHER question 2 or question 3. Each question is worth 32 points. CROSS OUT the question you choose not to answer. Only one question will be graded if answers are given to both questions.

Resources: You may use a calculator for this section. You may use the Periodic Table, the "Equations and Constants" sheet, and the table of standard reduction potentials provided by your instructor.

1. An equilibrium exists as shown below:

$PbI_2\ (s) \Leftrightarrow Pb^{2+}\ (aq) + 2I^-\ (aq)$ $\qquad K_{sp} = 8.7 \times 10^{-9}$

A. Write the K_{sp} expression for this equilibrium. (4 points)

$K_{sp} = [Pb^{2+}][I^-]^2$

B. Find the equilibrium concentrations for each ion. (10 points)

$K_{sp} = (x)(2x)^2 = 4x^3 = 8.7 \times 10^{-9}$ $\qquad x = 0.0013$

$[Pb^{2+}] = 0.0013\ M$

$[I^-] = 0.0026\ M$

C. Solid KI is added to 100.0 mL of a 0.12 M solution of $Pb(NO_3)_3$. How many grams of KI can be added before PbI_2 starts to precipitate out? Assume the KI does not add significant volume. (12 points)

$8.7 \times 10^{-9} = (0.12)(x)^2$ $\qquad x = 2.7 \times 10^{-4} = [I^-] = [KI]$

2.7×10^{-4} mol/L x 0.100 L x 166 g/mol = 4.5×10^{-3} grams of KI

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D. What would be the effect of adding solid PbI to the mixture in part c? Explain. (3 points)

No effect; PbI (s) as with all solids, does not appear in the equilibrium expression

E. Say Na_2SO_4 was added before the KI was. How would that affect the amount of KI that could be added before precipitation of PbI_2 begins? Explain. (3 points)

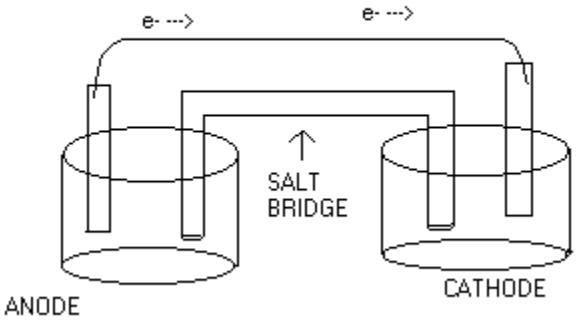
SO_4^{2-} would precipitate out some of the Pb^{2+}, allowing more KI to be dissolved since the $[Pb^{2+}]$ in the equilibrium expression would be less.

Answer EITHER question 2 (below) or question 3 (next page).

2. A voltaic cell is set up using zinc, nickel, and nitrate solutions of each at 25˚C.

Ni^{2+} (aq) + $2e^-$ → Ni (s) E° = – 0.25 V
Zn^{2+} (aq) + $2e^-$ →Zn (s) E° = – 0.763 V

A. Draw a generic voltaic cell, including all key components, and clearly showing the anode, cathode, and direction of electron flow. (5 points)



The students may or may not label the anode with zinc, etc., but it's not important that they do so. No points added or taken for this.

B. Show the reaction that occurs at: (10 points)

i) the anode:

Zn (s) → Zn^{2+} (aq) + $2e^-$ E° = + 0.763 V

ii) the cathode:

Ni^{2+} (aq) + $2e^-$ → Ni (s) E° = -0.25 V

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C. Calculate the $E°_{cell}$. (2 points)

$E°_{cell} = 0.763 + (-0.25) = 0.513$ V or 0.51 V

D. What is the E_{cell} after the concentration of the nickel ions is down to 0.05 M and the zinc ion concentration is 1.5M? Show all work. (10 points)

$E_{cell} = E°_{cell} - RT/nF \ln Q$

$E_{cell} = 0.513 - (8.314)(298)/(2)(96500) \ln(1.5/0.05)$

$E_{cell} = 0.469$ V or 0.47 V

E. Briefly explain how you would find K_{eq}. Include relevant equations. It is not necessary to actually solve for K_{eq}. (3 points)

Use $E°_{cell} = RT/nF \ln K$

Since at equilibrium, $E_{cell} = 0$ and $Q = K$

F. How could you recharge this cell? (2 points)

Apply electricity to reverse (nonspontaneous) direction.

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3. Iron is one of our most valuable resources. The problem is how to obtain pure metallic Fe from its compounds, such as iron(III)oxide?

A. One method is to heat the iron(III)oxide until it decomposes into pure Fe(s) and oxygen gas.

i. Write a balanced equation for this process. (5 points)

$2\ Fe_2O_3 \rightarrow 4\ Fe + 3\ O_2$

ii. Given the following thermodynamic data, calculate the $\Delta G°_{rxn}$ at 25°C. (7 points)

$\Delta H°_{rxn}$ = + 824 kJ and $\Delta S°_{rxn}$ = +275 J/K

$\Delta G°_{rxn} = \Delta H°_{rxn} - T\Delta S°_{rxn} = 824\ kJ - (298)(0.275\ kJ) = 742\ kJ$

iii. Calculate the temperature at which this process will be spontaneous. (7 points)

$T = \Delta H°_{rxn} / \Delta S°_{rxn} = 824\ kJ / 0.275\ kJ = 2996\ °C$
$(\text{or } 3.00 \times 10^3\ °C)$

B. Since the first method seems unreasonable, a second method is to couple the reaction in A(i) with the oxidation of aluminum:

$2Al\ (s) + 3/2O_2\ (g) \rightarrow Al_2O_3\ (s)$

(i) The overall reaction is called the "Thermite" reaction. Use Hess's Law to obtain a net reaction that does not contain any O_2 (the O_2 cancels). Show your work. (5 points)

$2\ Fe_2O_3 \rightarrow 4\ Fe + 3\ O_2$

$+\{2Al\ (s) + 3/2O_2\ (g) \rightarrow Al_2O_3\ (s)\} \times 2$

$2\ Fe_2O_3 + 4\ Al \rightarrow 4\ Fe + 2\ Al_2O_3$

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(ii) If the $\Delta G°_{rxn}$ for the overall reaction = – 840. kJ, what is the $\Delta G°_{rxn}$ for the oxidation of the aluminum? (6 points)

$\Delta G°_{rxn}$ (overall) = $\Delta G°_{rxn}$ (decomposition of iron oxide) + $\Delta G°_{rxn}$ (oxidation of Al)

– 840. kJ = 742 kJ + $\Delta G°_{rxn}$ (oxidation of Al)

$\Delta G°_{rxn}$ (oxidation of Al) = – 1582 kJ for the reaction as in the Hess's law problem OR

– 1582 kJ ÷ 2 = – 791 kJ for the original oxidation reaction.

C. Would you expect the oxidation of aluminum to be exothermic or endothermic? Explain. (2 points)

$\Delta S°_{rxn}$ must be negative here because 3/2 mole gas as reactant and no moles of gas product. Since the $\Delta G°_{rxn}$ is also negative, then $\Delta H°_{rxn}$ must be negative.

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Section III

Time Limit: You have 50 minutes to complete this section.

Scoring: 96 points total; Questions 4 and 5 are mandatory and are worth 48 points (24 points each). Choose ONE question from questions 6-7. Each question is worth 32 points. CROSS OUT the question you choose not to answer. Only one question will be graded if answers are given to both questions.

Resources: You may not use a calculator for this section. You may use the Periodic Table, the "Equations and Constants" sheet, and the table of standard reduction potentials provided by your instructor.

4. Write the formulas to show the reactants and products for any SIX of the laboratory situations described below. A reaction occurs in all cases. All solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equation.

A. Solid sodium oxide is reacted with sulfur dioxide gas.

$Na_2O + SO_2 \rightarrow Na_2SO_3$

B. Hydrofluoric acid is added to a solution of calcium hydroxide.

$HF + OH^- \rightarrow H_2O + F^-$

C. A solution of lead (II) nitrate is added to a solution of sodium hydroxide.

$Pb^{2+} + OH^- \rightarrow Pb(OH)_2$

D. Solid magnesium is placed in a solution of dilute nitric acid.

$Mg + H^+ + NO_3^- \rightarrow Mg^{2+} + NO + H_2O$

E. Concentrated ammonia solution is added to a solution of copper (II) chloride.

$Cu^{2+} + NH_3 \rightarrow Cu(NH_3)_4^{2+}$ (note: the number of ammonia ligands can vary, but the charge on the complex must be accurate)

F. Solid potassium carbonate is heated.

$K_2CO_3 \rightarrow K_2O + CO_2$

G. Solid calcium is heated with oxygen gas.

$Ca + O_2 \rightarrow CaO$

H. Methane is burned in air.

$CH_4 + O_2 \rightarrow CO_2 + H_2O$

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5. A reaction occurs as shown:

$$CO\ (g) + NO_2\ (g) \rightarrow CO_2\ (g) + NO\ (g)$$

At 25ºC, the following rate data was collected:

Initial concentrations (M)		**Initial Rate (mol/L·hr)**
[CO]	**[NO_2]**	
3.9×10^{-3}	**2.6×10^{-4}**	**2.6×10^{-7}**
7.8×10^{-3}	**2.6×10^{-4}**	**5.1×10^{-7}**
7.8×10^{-3}	**7.8×10^{-4}**	**15×10^{-7}**

A. Write the overall rate law for this reaction. (8 points)

Students can show by discussion or by algebra of rate and concentration comparisons:

rate = $k[CO][NO_2]$

B. What is the overall order of the reaction? (2 points)

2

C. Calculate k, include appropriate units. (4 points)

$k = 2.6 \times 10^{-7} / (3.9 \times 10^{-3})\ (\ 2.6 \times 10^{-4}) = 2.6 \times 10^{-1}$ L/mol·hr

D. If the slope of lnk vs. 1/T = -2.72×10^4, then calculate E_a for this reaction. (5 points)

E_a/R = - slope = + 2.72×10^4

$E_a = (2.72 \times 10^4)(0.008314) = 226$ kJ/mol

E. Could the overall equation be a single elementary step in a reaction mechanism? Explain. (3 points)

Yes, it is between 2 particles (bimolecular) which is reasonable and common, and it matches the overall rate law as an single elementary reaction (which by default would be the slow step).

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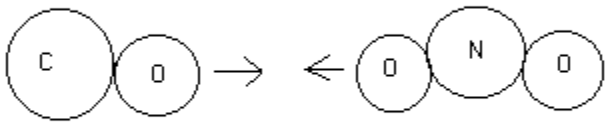
F. If E were true, draw how the molecules would likely need to be oriented in order for an effective collision, resulting in reaction, to occur. (2 points)



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Full Name_____ **User Name** _____ **Date** _____
(print clearly)

Answer ONE of the following two questions. Only one of these questions will be graded. If you start both questions, clearly indicate the question you do not want graded.

6. Read through each of the following questions on atomic structure before deciding which problem to choose between this and problem #7.

A. Which of Na or K has the highest ionization energy? Explain. (10 points)

Na has higher IE because it has one fewer principle energy levels; so its valence electron can get closer to the nucleus and is held more tightly, despite the higher # of protons in the K nucleus.

B. The first three ionization energies for an unknown metal are shown below. Is this metal most likely an alkali metal or an alkaline earth metal. Explain. (7 points)

First Ionization Energy = 899 kJ/mol
Second Ionization Energy = 1757 kJ/mol
Third Ionization Energy = 14850 kJ/mol

This is an alkaline earth metal because the largest jump is between the 2^{nd} and 3^{rd} IE, indicating that the 3^{rd} electron to be removed is from an inner energy level, and therefore has 2 electrons on its valence energy level.

C. The Rydberg equation, shown below, can be used to predict the position and wavelength of any line in the spectrum of a one-electron species.

$1/\lambda = R\,[1/n_1^2 - 1/n_2^2]$ where R is the Rydberg constant, $1.097 \times 10^7\ m^{-1}$

What is the frequency of light needed to remove an electron from n = 1 to infinity from a hydrogen atom (to ionize hydrogen)? (10 points)

$1/\lambda = R$ (1) Therefore $\lambda = 1/R = 9.116 \times 10^{-8}$ m

$v = c / \lambda = 3.00 \times 10^8$ m/s / 9.116×10^{-8} m

$v = 3.29 \times 10^{15}\ s^{-1}$

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D. The frequency of light emitted from electron transitions between sequential principle energy levels decreases as these transitions occur farther and farther from the nucleus. What can you conclude about the spacing and relative energies of principle energy levels in atomic structure? (5 points)

The spacing gets closer and closer farther out, as the difference in energy between principle energy levels decreases.

7. Two beakers each contain 1.0 Kg of water. To the first beaker, 1.0 mole of solute A is added, and to the second 1.0 mole of solute B is added.

A. The vapor pressure above the solution with A decreased, but the vapor pressure above the solution with B increased. What can you conclude about each solute? (10 points)

Solute A is nonvolatile; Solute B is volatile, and more so than water

B. What would happen to each solution if the two were placed together in a small, closed container, with no lid directly on either beaker? (5 points)

In theory, the one with the higher vapor pressure will decrease in volume while the one with the lower vapor pressure will increase in volume.

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C. In a separate experiment, 5.0 mol of solute A is found to raise the boiling point of 1 Kg of pure water by 7.8°C Choose from the following list which of those shown would most likely substance A and explain why: K_b water = 0.52 °C/*m* (10 points)

Glucose, NaCl, HBr, $CaCl_2$, or H_2SO_3

$\Delta T = iK_b\, m$

$7.8\ ^oC = i(0.52)\, m$

$(i)(m) = 15$ = mol solute/ Kg solvent; since there is 1 Kg of solvent, then there are (3)(5) mol of solute.

Since only 5.0 mol of solute was added, it must have split into three particles, (van't Hoff factor = 3) which best matches $CaCl_2$

Note: Students may put H_2SO_3 which should be give some partial credit; however this is a weak acid, and in any case polyprotic acids do not exist completely dissociated in solution.

D. What happens to the vapor pressure of both solutions as the temperature is raised? Explain clearly on a molecular level what is occurring. (7 points)

The vapor pressure of both solutions increases as the increased temperature means increased kinetic energy of the particles…more have enough KE to overcome the intermolecular forces holding them in the liquid state, so that more escape to the vapor phase.

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